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CHEMISTRY
HIGHER LEVEL
PAPER 2

Wednesday 12 May 2010 (afternoon)

2 hours 15 minutes

Candidate session number

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INSTRUCTIONS TO CANDIDATES

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Section A: answer all of Section A in the spaces provided.
- Section B: answer two questions from Section B. Write your answers on answer sheets. Write your session number on each answer sheet, and attach them to this examination paper and your cover sheet using the tag provided.
- At the end of the examination, indicate the numbers of the questions answered in the candidate box on your cover sheet and indicate the number of sheets used in the appropriate box on your cover sheet.

0114

SECTION A

*Answer **all** the questions in the spaces provided.*

1. The percentage by mass of calcium carbonate in eggshell was determined by adding excess hydrochloric acid to ensure that all the calcium carbonate had reacted. The excess acid left was then titrated with aqueous sodium hydroxide.

(a) A student added 27.20 cm^3 of 0.200 $mol\,dm^{-3}$ HCl to 0.188 g of eggshell. Calculate the amount, in mol, of HCl added. *[1]*

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(b) The excess acid requires 23.80 cm^3 of 0.100 $mol\,dm^{-3}$ NaOH for neutralization. Calculate the amount, in mol, of acid that is in excess. *[1]*

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(c) Determine the amount, in mol, of HCl that reacted with the calcium carbonate in the eggshell. *[1]*

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(d) State the equation for the reaction of HCl with the calcium carbonate in the eggshell. *[2]*

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(e) Determine the amount, in mol, of calcium carbonate in the sample of the eggshell. *[2]*

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(This question continues on the following page)

(Question 1 continued)

(f) Calculate the mass **and** the percentage by mass of calcium carbonate in the eggshell sample. *[3]*

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(g) Deduce **one** assumption made in arriving at the percentage of calcium carbonate in the eggshell sample. *[1]*

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2. (a) Draw and label an energy level diagram for the hydrogen atom. In your diagram show how the series of lines in the ultraviolet and visible regions of its emission spectrum are produced, clearly labelling each series. *[4]*

(b) On the above diagram, draw the line that corresponds to the first ionization energy of hydrogen and explain your reasoning. *[2]*

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3. Consider the bonding and structure of the period 3 elements.

(a) Explain the increase in the melting point from sodium to aluminium. *[2]*

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(b) Explain why sulfur, S_8, has a higher melting point than phosphorus, P_4. *[2]*

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(c) Explain why silicon has the highest melting point and argon has the lowest melting point. *[2]*

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4. One important property of a rocket fuel mixture is the large volume of gaseous products formed which provide thrust. Hydrazine, N_2H_4, is often used as a rocket fuel. The combustion of hydrazine is represented by the equation below.

$$N_2H_4(g) + O_2(g) \rightarrow N_2(g) + 2H_2O(g) \qquad \Delta H_c^{\ominus} = -585\,kJ\,mol^{-1}$$

(a) Hydrazine reacts with fluorine to produce nitrogen and hydrogen fluoride, all in the gaseous state. State an equation for the reaction. *[2]*

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(b) Draw the Lewis structures for hydrazine and nitrogen. *[2]*

(c) Use the average bond enthalpies given in Table 10 of the Data Booklet to determine the enthalpy change for the reaction in part (a) above. *[3]*

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(Question 4 continued)

(d) Based on your answers to parts (a) and (c), suggest whether a mixture of hydrazine and fluorine is a better rocket fuel than a mixture of hydrazine and oxygen. *[2]*

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(e) Comment on the environmental safety of the products of the reaction of N_2H_4 with O_2 **and** the reaction of N_2H_4 with F_2. *[1]*

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5. Existence of isomers leads to diversity of organic compounds.

(a) Describe what is meant by the term *stereoisomers*. *[2]*

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(b) 1,3-dichlorocyclobutane exists as geometrical isomers, a form of stereoisomers.

(i) Draw and name the **two** geometrical isomers of 1,3-dichlorocyclobutane. *[2]*

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(ii) Identify the isomer with the **higher** boiling point and explain your reasoning. *[3]*

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SECTION B

*Answer **two** questions. Write your answers on the answer sheets provided. Write your session number on each answer sheet, and attach them to this examination paper and your cover sheet using the tag provided.*

6. The periodic table shows the relationship between electron configuration and the properties of elements and is a valuable tool for making predictions in chemistry.

(a) Identify the property used to arrange the elements in the periodic table. *[1]*

(b) (i) Define the term *electronegativity*. *[2]*

(ii) Outline **two** reasons why electronegativity increases across period 3 in the periodic table and **one** reason why noble gases are not assigned electronegativity values. *[3]*

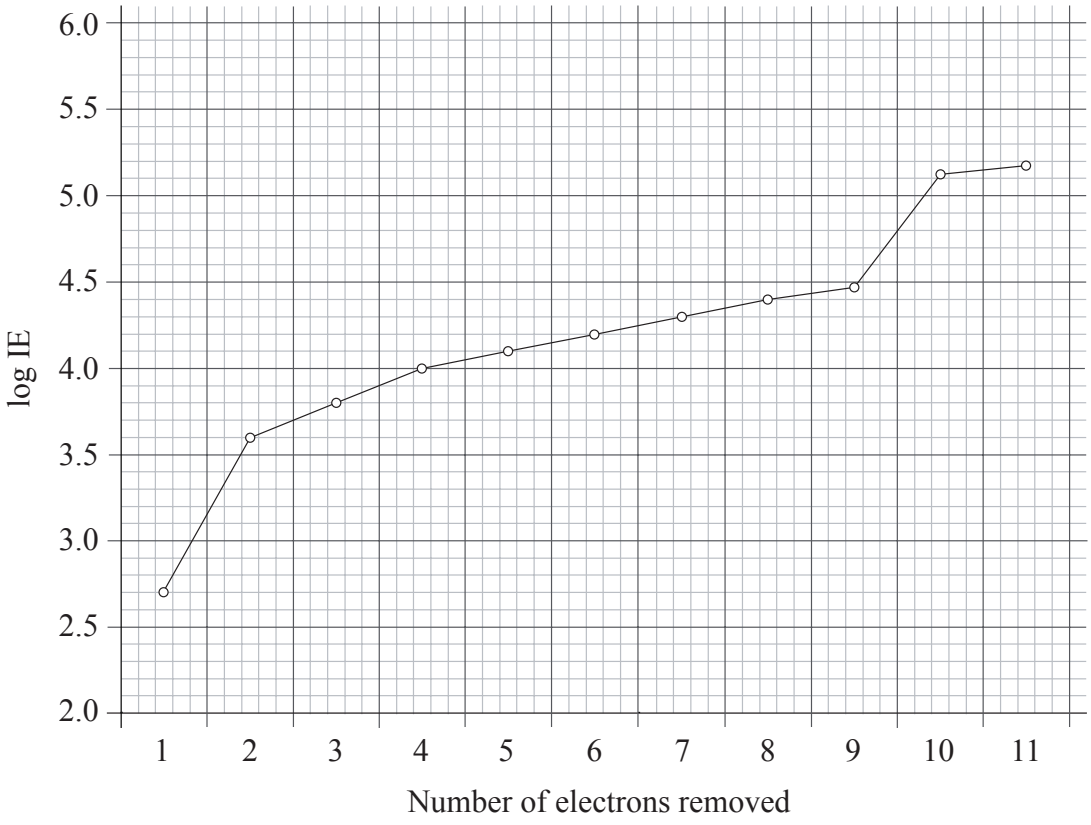
(c) (i) Outline **two** reasons why a sodium ion has a smaller radius than a sodium atom. *[2]*

(ii) Explain why the ionic radius of P^{3-} is **greater** than the ionic radius of Si^{4+}. *[2]*

(This question continues on the following page)

(Question 6 continued)

(d) The graph below represents the successive ionization energies of sodium. The vertical axis plots log (ionization energy) instead of ionization energy to allow the data to be represented without using an unreasonably long vertical axis.



State the full electron configuration of sodium and explain how the successive ionization energy data for sodium are related to its electron configuration. *[4]*

(e) (i) Explain why the first ionization energy of aluminium is **lower** than the first ionization energy of magnesium. *[2]*

(ii) Explain why the first ionization energy of sulfur is **lower** than the first ionization energy of phosphorus. *[2]*

(f) The ten elements in the first-row d-block have characteristic properties and many uses.

(i) State and explain the type of reaction that takes place between Fe^{3+} and H_2O to form $[Fe(H_2O)_6]^{3+}$ in terms of acid-base theories. *[2]*

(ii) Explain why $[Fe(H_2O)_6]^{3+}$ is coloured. *[3]*

(iii) Outline the economic significance of the use of a catalyst in the Haber process which is an exothermic reaction. *[2]*

7. (a) Water is an important substance that is abundant on the Earth's surface.

(i) State the expression for the ionic product constant of water, K_w. *[1]*

(ii) Explain why even a very acidic aqueous solution still has some OH^- ions present in it. *[1]*

(iii) State and explain the effect of increasing temperature on the value of K_w given that the ionization of water is an endothermic process. *[3]*

(iv) State and explain the effect of increasing temperature on the pH of water. *[2]*

(b) Buffer solutions resist small changes in pH. A phosphate buffer can be made by dissolving NaH_2PO_4 and Na_2HPO_4 in water, in which NaH_2PO_4 produces the acidic ion and Na_2HPO_4 produces the conjugate base ion.

(i) Deduce the acid and conjugate base ions that make up the phosphate buffer and state the ionic equation that represents the phosphate buffer. *[3]*

(ii) Describe how the phosphate buffer minimizes the effect of the addition of a strong base, $OH^-(aq)$, to the buffer. Illustrate your answer with an ionic equation. *[2]*

(iii) Describe how the phosphate buffer minimizes the effect of the addition of a strong acid, $H^+(aq)$, to the buffer. Illustrate your answer with an ionic equation. *[2]*

(c) A 0.10 mol dm^{-3} ammonia solution is placed in a flask and titrated with a 0.10 mol dm^{-3} hydrochloric acid solution.

(i) Explain why the pH of the ammonia solution is less than 13. *[2]*

(ii) Estimate the pH at the equivalence point for the titration of hydrochloric acid with ammonia and explain your reasoning. *[2]*

(iii) State the equation for the reaction of ammonia with water and write the K_b expression for $NH_3(aq)$. *[2]*

(iv) When half the ammonia has been neutralized (the half-equivalence point), the pH of the solution is 9.25. Deduce the relationship between $[NH_3]$ and $[NH_4^+]$ at the half-equivalence point. *[1]*

(v) Determine pK_b and K_b for ammonia based on the pH at the half-equivalence point. *[3]*

(vi) Describe the significance of the half-equivalence point in terms of its effectiveness as a buffer. *[1]*

8. The word *redox* comes from a combination of the terms *reduction* and *oxidation*. Redox reactions affect our daily lives.

(a) The overall reaction that takes place in a voltaic cell is shown below.

$$Pb(s) + PbO_2(s) + 2H_2SO_4(aq) \rightarrow 2PbSO_4(s) + 2H_2O(l)$$

(i) Determine the oxidation number of lead in Pb, PbO_2 and $PbSO_4$. *[1]*

(ii) Deduce the oxidation and reduction half-equations taking place at the negative lead electrode (anode) and the positive lead(IV) oxide electrode (cathode). Deduce the oxidizing and reducing agents and state the direction of the electron flow between the electrodes. *[4]*

(iii) In order to determine the position of three metals in a reactivity series, the metals were placed in different solutions of metal ions. The table below summarizes whether or not a reaction occurred.

	$Ag^+(aq)$	**$Cu^{2+}(aq)$**	**$Pb^{2+}(aq)$**
Ag (s)		No reaction	No reaction
Cu (s)	Reaction		No reaction
Pb (s)	Reaction	Reaction	

State the equations for the **three** reactions that take place. Use this information to place the metals Ag, Cu and Pb in a reactivity series, with the strongest reducing agent first, and explain your reasoning. *[5]*

(iv) Use information from Table 14 of the Data Booklet to deduce the oxidizing agent that can oxidize chloride ions but not fluoride ions. State the redox equation for the reaction and determine its cell potential. *[4]*

(b) (i) **Molten** sodium chloride is electrolysed in a cell using inert electrodes. State the half-equation, with state symbols, for the reaction taking place at the positive electrode (anode) and for the reaction taking place at the negative electrode (cathode). Determine the mole ratio of the products formed. *[3]*

(ii) Predict and explain the products of electrolysis of a **concentrated** solution of NaCl(aq) using inert electrodes. Your answer should include half-equations with state symbols for the reaction at **each** electrode. *[4]*

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(Question 8 continued)

(c) Electroplating is an important application of electrolytic cells with commercial implications. Copper may be plated using an electrolytic cell with an aqueous acidified copper(II) sulfate electrolyte.

For the copper plating of tin to make jewellery, state the half-equation at **each** electrode. Assume the other electrode is also inert. Suggest **two** observations that you would be able to make as the electroplating progresses. *[4]*

9. (a) Alkenes are an economically and chemically important family of organic compounds.

(i) The reaction of alkenes with bromine water provides a test for unsaturation in the laboratory. Describe the colour change when bromine water is added to chloroethene. *[1]*

(ii) Deduce the Lewis structure of chloroethene and identify the formula of the repeating unit of the polymer poly(chloroethene). *[2]*

(iii) Besides polymerization, state **two** commercial uses of the reactions of alkenes. *[2]*

(b) Halogenoalkanes undergo two major types of reaction leading to the formation of different organic compounds.

(i) 1-bromopropane can be converted to 1-butylamine (butan-1-amine) in **two** stages. Draw the structural formulas of 1-bromopropane and 1-butylamine (butan-1-amine). *[1]*

(ii) Deduce a reaction pathway for the **two**-stage conversion of 1-bromopropane to 1-butylamine (butan-1-amine). Your answer should include an equation for each stage of the reaction **and** the reaction conditions for the second stage. *[4]*

(c) (i) Describe the elimination of HBr from bromoethane. Your answer should include the reagents, conditions and equation for the reaction. *[3]*

(ii) Explain the mechanism for the elimination of HBr from bromoethane. *[5]*

(d) But-2-ene can be converted to butan-2-one in **two** stages.

(i) Draw the structural formulas of but-2-ene and butan-2-one. *[2]*

(ii) Deduce a reaction pathway for the **two** stages of the reaction. Your answer should include the fully balanced equation for each stage of the reaction **and** the reagents and conditions for the two stages. *[5]*